W. B. No. 252.

U. S. DEPARTMENT OF AGRICULTURE,

WEATHER BUREAU.

INSTRUCTIONS

FOR THE

CARE AND MANAGEMENT OF SUNSHINE RECORDERS.

CIRCULAR G, INSTRUMENT DIVISION.

SECOND EDITION.

BY

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PROFESSOR OF METEOROLOGY.

Prepared under direction of WILLIS L. MOORE, Chief U. S. Weather Bureau.

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1901.

NOTE TO OBSERVERS.

U. S. DEPARTMENT OF AGRICULTURE,
WEATHER BUREAU,

Washington, D. C., September 1, 1901.

The special instructions contained in this circular are for the information and guidance of observers of the Weather Bureau, and will be carefully followed in connection with the care and management of sunshine recorders.

WILLIS L. MOORE,
Chief U. S. Weather Bureau.

NOTE.—A former publication, Circular G (Instrument Room) 1894, containing "Instructions for use of Combined Maximum and Minimum Soil Thermometers" is now obsolete as a Weather Bureau publication. The Division of Soils was then a part of the Weather Bureau but was made an independent division of the Department of Agriculture in 1895, and is now designated the Bureau of Soils, U. S. Department of Agriculture.

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U. S. WEATHER BUREAU SUNSHINE RECORDERS.

1. *The registration of sunshine.*—Up to the present time the records of sunshine consist of what may more properly be called records of the duration of bright sunshine. With one or two exceptions recorders do not measure the brightness or intensity of the sunshine. A certain brightness of sunshine, which differs more or less with different instruments, causes the record to be formed and no appreciable or important change in the appearance of these records results from still brighter or even the brightest sunshine, whereas the record is blank for all degrees of intensity less than that sufficient to start a record. It is very desirable that better and more complete methods of registration be devised, but as yet the apparatus producing intensity records is not sufficiently satisfactory and simple to justify its general introduction. Those instruments which aim to record intensity consist generally of two thermometers, the bulb of one of which is coated with lampblack. The records are really records of temperature of black and bright-bulb thermometers exposed to radiation and insolation, and give but an imperfect measure of solar radiation.

2. Three forms of recorders of bright sunshine are in use, namely: (*a*) The Campbell-Stokes burning recorder, which consists of a ground and polished crystal sphere, that acts as a lens, or burning glass, and scorches a trace showing the duration of bright sunshine upon a strip of cardboard placed at the proper focal distance from the sphere; (*b*) the Jordan, or photographic recorder, a modified form of which is used by the Weather Bureau, and finally, (*c*) the electrical thermometric recorder, also in use at Weather Bureau stations. These latter are fully described further on.

3. *Exposure of instrument.*—It need scarcely be said that the point selected for the exposure of the sunshine recorder should command an uninterrupted view of the sun at all hours of the day and at all seasons of the year. A slender flagstaff, or similar object, may intervene with no more serious result than to produce a slight break in the continuity of the record of sunshine at the same hour every day. Regard should be had for the horizon also, especially those portions of it at which the sun rises and sets at the different seasons of the year. As will be found hereafter, some allowance must be made for loss of record during early morning and late afternoon hours of sunshine, owing to imperfect sensitiveness of the instruments, and for this reason low obstructions near the horizon points will probably not affect the records.

4. *Support.*—A support similar in design to that shown in fig. 1 will be very satisfactory in nearly all cases. It should be securely fastened down so that there will be no danger of its blowing over in heavy winds. The height must, of course, depend upon the exposure selected. At some places it may be found preferable to place the recorder on a fire wall or a dead chimney, fastening it to a block of wood, which should be securely attached to the brick or stonework. In some cases a good support may be made by attaching the recorder to a wooden bracket, or arm, nailed to the roof or a corner of a building. Wherever the support is placed it should be located so as to be easily accessible, in order that the recorder may conveniently be given the necessary attention.

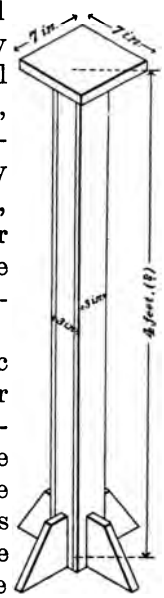

Fig. 1.—Support.

5. *Description of instrument.*—The photographic sunshine recorder consists of a closed metal cylinder supported upon a frame, so that the axis of the cylinder can be set in an inclined position parallel to the axis of the earth, according to the latitude of the place of observation. The interior of the cylinder is fitted with curved pieces of metal adapted to receive and hold sheets of sensitized photographic paper (blue print or ferro-prussiate paper). Two notched slides, *A B*, fig. 2, each provided with a thin-edged pin hole, as indicated at *h*, are fitted to the sides of the cylinder, and so arranged that the slides can be set and held by aid of the notches in successive positions, corresponding to the days of a month. When properly mounted and exposed to direct sunshine, a small beam of light passes through the pin hole in one or the other of the slides, according to the time of day, and impinges upon the sensitive paper within. The slide *B* faces toward the sun during the forenoon, and during the afternoon the sun shines more directly upon the slide *A*. For a brief period at noontime the sun shines about equally upon both slides. The beam of sunlight impinging upon the sensitized paper moves across the surface as the position of the sun in the sky changes from hour to hour, and produces thereby, as a result of its action upon the chemically prepared paper, a line or trace which is continuous if the sunshine is continuous, but is interrupted by blank spaces corresponding to periods of cloudiness when the sun is obscured by clouds. The shifting of the slides to successive positions from day to day causes the traces upon the paper for the several days to appear in separate and distinct positions, and the record of sunshine for an entire month may thus be produced upon two small sheets of paper, one containing the record of sunshine from sunrise to noon, the other from noon to sunset.

PHOTOGRAPHIC SUNSHINE RECORDER.

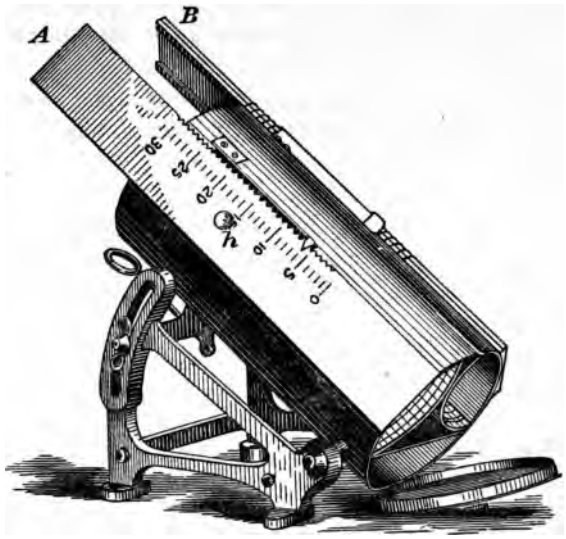

Fig. 2.—Photographic sunshine recorder.

6. It is generally well known that the ordinary blue print paper, after having received a chemical impression by light in any prescribed manner, is fixed and rendered permanent by simply washing in plenty of clean water, and is thereafter no longer affected by any further action of light. The charts of the photographic recorder wash out white, or nearly so, marked by blue lines representing the sunshine record.

7. *Adjustment.*—The photographic recorder, when mounted upon its support, is properly adjusted when the axis of the cylinder is parallel to the axis of the earth. The sun will then apparently pass over it in a circle, the plane of which cuts the cylinder approximately at right angles to its axis. The records from a properly adjusted instrument will consist of straight lines or traces at right angles to the ruled hour lines. A great variety of curved lines or traces will be obtained if the instrument is improperly adjusted, as will be explained later.

8. To obtain a proper adjustment of the photographic recorder the top surface of the support should be carefully leveled, and a true north and south line should be drawn thereon. This line may be located by use of a magnetic needle, making due allowance for the magnetic declination of the station and guarding against any influence upon the needle that may arise from the presence of iron upon the roof or in the structure of the building. Probably a more trustworthy result will be obtained by aid of the pole star at night. For this purpose a long plumb line will be required, so arranged that with the head in a fixed position the

eye may sight across the plumb line to the north star, and, without moving the head, over the top of the support to the plumb line. A straightedge may be laid across the support, and adjusted to coincide with the north and south line of sight.

Having drawn the north and south line upon the support, the frame of the instrument is screwed thereon so that its sides are in the north and south directions.

To place the axis of the cylinder parallel to the earth's axis it is necessary only to incline the cylinder at such an angle that the bolt moving in the slotted and graduated arc on the frame of the recorder is set opposite to the degree mark corresponding to the latitude of the station.

9. *Record sheets.*—The record sheets employed with this recorder consist of the well-known "blue print" or ferro-prussiate paper, which can be procured from any of the dealers in photographic supplies. The Weather Bureau stations are supplied monthly from the Central Office with freshly sensitized sheets in printed forms, and these will be used exclusively except that in cases of loss or injury of the regular sheets the observer is authorized to use any paper available upon which a record can be obtained.

10. The official record sheets are ruled with vertical lines corresponding to the hours of possible sunshine. Across the bottom of the sheets are a series of lines corresponding to the months of the year, as indicated by the printed names of the months. When the sensitized sheet is to be placed within the recorder it must be trimmed across the bottom at the line *just beneath the name of the month* for which the sheet is to be the record. The purpose of trimming the sheet at the monthly lines is to cause the sheet to take a different position in the cylinder from month to month, corresponding to the changing positions of the sun north or south of the equator, with the result that the successive daily lines or traces of the sunshine constituting the record will fall very nearly upon the same portions of the sheet. Otherwise, it would be difficult to identify the several lines of record and determine the day of the month to which they correspond, each to each.

11. The sheets must be further trimmed across the top, the sides, and center along dotted lines ruled thereon in such manner as to fit closely the curved surfaces within the recorder. The two parts of the sheet (that is, the parts for the forenoon and the afternoon sunshine, respectively) will be slipped into their appropriate compartments, taking care that the sheet for the forenoon record will face the east, while that for the afternoon record will face toward the west, *and that neither sheet is upside down.*

12. It will be found the curved surfaces adapted to receive the sheets may be wholly withdrawn from the cylinder, which circumstance may sometimes be of assistance in inserting or removing

record sheets. When in proper position the bottom edge of the sheets must be just flush with the bottom ends of the curved metal plates. The sheets are prevented from slipping by means of the rectangular wire frames fitting within the recorder.

13. The trimming and changing of sheets are most safely performed in a dimly-lighted room, or, preferably, at nighttime by artificial light, and for this purpose the recorder is constructed so that the closed cylinder can be easily removed from the frame without either exposing the record sheets or disturbing the adjustment of the instrument. The sheets are, therefore, best trimmed and placed in the recorder after sunset of the last day of the month (except when it is desired to commence a record other than on the first of a month), the slides of the recorder set to their proper places to register for the following day, and the instrument replaced on its support.

14. While the blank sensitized sheets may be used during an entire month, it has been found that much better records are obtained if the sheets are changed on the 1st and 15th of each month. Sheets will, therefore, be changed twice a month at such stations as receive two sets per month from the Central Office.

15. Great care must be taken before the prepared sheets are finally rendered permanent not to expose them to daylight, as they will thus be rendered worthless for the purpose for which they are intended. The metal cylinder should, therefore, always be removed to the office room before opening.

16. After sunset of the last day (or 15th) of the month, the cylinder will be removed to the office, the sheets taken therefrom, and the record rendered permanent in accordance with the instructions contained in paragraph 18. New sensitized sheets will then be inserted and the instrument exposed.

17. It is necessary, to secure proper records, that the sheets be fitted smoothly and perfectly to the curved surfaces within the closed cylinder. If the sheets are carelessly trimmed and improperly placed within the recorder, they may curl up and change their position and cause defective and probably incomplete records.

18. The records obtained upon sheets that have been exposed are rendered permanent when taken from the instrument by simply washing in water, and afterwards drying them between sheets of clean blotting paper in a letter press. The sheets should be immersed in running water, if possible, for a half hour or more, or until the surface of the paper becomes nearly white and the sunshine record is brought out in a bright, blue color.

19. *Preparation of Form No. 1065.*—The photographic sheets containing the month's record of sunshine will be neatly pasted in the appropriate spaces on Form No. 1065, which will be filled out with the proper dates and headings.

20. Owing to slight imperfections in the construction of the instruments, and to the difficulty of obtaining perfect adjustments, it will sometimes be found that the record lines or traces of sunshine made upon the record sheets are not perfectly straight, which should be the case as has been previously explained in paragraph 7. If the lines are seriously curved and inclined the instrument has not been properly adjusted and should be reset. It is, therefore, important that the observer should understand the significance of the various forms of record lines.

21. If, for instance, it is found that when the sheets are taken out and placed with the noon lines together, the record for the day is a *convex* line, that is, nearer the top of the sheet at noon than during the morning and evening hours, a little consideration will show that this results because the north end of the cylinder is *not* sufficiently elevated for the latitude of the station. On the other hand, if the record is *concave* it indicates that the north end of the cylinder is elevated *too much* for the latitude of the station.

22. Again, if the record line, instead of being at right angles to the ruled hour lines, crosses them obliquely, so as to be nearer the top of the sheet on the p. m. than on the a. m. side, it indicates that the north end of the cylinder is too far to the east, while, if it is nearer the top during the a. m. than during the p. m., it indicates that the north end of the cylinder is too far to the west.

23. A combination of faulty adjustments for latitude and meridian will produce in the record line a combination of the oblique with the concave or convex effect, as the case may be. For instance, if the north end of the cylinder is too low, and a little too far to the east, the result will be a concave line, the p. m. part of which is nearer the top of the sheet than the a. m. part. It may even take the form of a very oblique line during the a. m., and a line very nearly straight and at right angles to the ruled hour lines during the p. m. The observer must decide for himself to what errors of adjustment he is to attribute the other possible combinations of an oblique line with the concave or convex line.

24. Even when satisfactory adjustments for latitude and meridian have been obtained, the time element may not be exactly right, owing to instrumental imperfections and variations in the trimming of the sheets. When a new instrument has been set in operation the "time" will be checked on at least two days during the month; the one near the beginning of the month and the other near its close. The check is made as follows: At 10 a. m., *local time*, move the slide of the recorder facing the forenoon sunshine down *half* a notch, allowing it to remain there for a period of five minutes, then returning it to its original position. At 2 p. m. in the afternoon of the same or another day, move the

afternoon slide of the recorder down and back in the same manner. If more convenient, the tests may be made at any other times, but integral hours should be chosen, if possible, but they should not be near sunrise, noon, or sunset. It is essential, of course, that the tests be made during bright sunshine.

25. In the later editions of Form No. 1065, hour lines are printed thereon in the same manner as upon the sensitized record sheets. With a little care in pasting the record sheets upon this form it will be possible to adjust the record so that the time lines on Form No. 1065 when drawn across the record will give the true time. Similarly, these lines will assist in establishing hour lines upon a blank sheet of paper containing a sunshine record.

26. If, when the sheets are removed at the end of the month, it is found necessary to adjust the instrument, a note will be made on the margin of Form No. 1065 for the month just past, stating in what manner the adjustment has been changed.

27. *Time error.*—The period of five minutes (mentioned in paragraph 24) should begin two and a half minutes before the hour, and end two and a half minutes after the hour closes; bearing in mind that the time should be *true local time.*

The short record lines, made while the slides are displaced from their normal positions, will show by their relation to the corresponding hour lines on the record sheets the time error of the recorder. If such an error exists, corrected hour lines will be drawn in red ink on the forms through the *centers* of the short record lines mentioned above.

28. Having determined the time error, we must remember that it may result from both instrumental imperfections and the equation of time. All records of sunshine obtained from the photographic recorder are made on *apparent* solar time, which differs from *mean* solar or *clock* time by a variable amount, called the "equation of time." The curved line, fig. 3, shows approximately the variations in the equation of time throughout the year. When the + sign applies it indicates that clock time is *faster* than sun time, and when the − sign applies it indicates that clock time is *slower* than sun time. By the aid of this diagram the observer can judge whether the time error, as shown by the time check made as directed in paragraph 24, is due to the equation of time, or to instrumental imperfections.

If the time check falls *before* the hour line corresponding to the time at which they were made by a greater amount than corresponds to the equation of time for that day, then the west side of the instrument is too low, and, conversely, if they fall *after* the hour line by a greater amount than due to the equation of time, the east side of the instrument is too low.

Slight errors of this character affecting both forenoon and afternoon records about equally can be corrected by placing thin washers or strips of wood under the feet of the side of the instrument that is too low, but no attempt will be made to correct the adjustment on account of errors due to this cause unless they exceed five minutes.

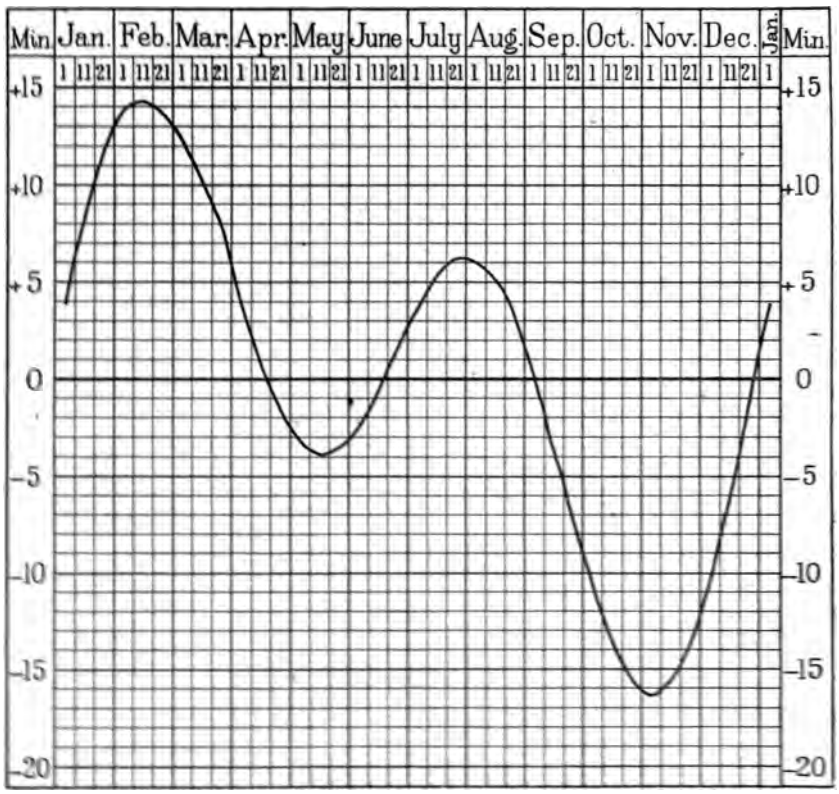

Fig. 3.—Diagram of equation of time.

29. Each night, after sunset, the slides will be moved downward one notch, in order that the recorder may be in readiness for the next day's record.

30. The cylinder can be removed, when desired, by withdrawing the log pin provided for this purpose. Care should be taken, however, never to disturb the position of the frame after the recorder has been once properly adjusted.

THERMOMETRIC SUNSHINE RECORDER, ELECTRICAL.

DESCRIPTION.

31. A sectional view of the glass portion of this instrument, of the present pattern, is shown in fig. 4. The principle is essentially that of a Leslie differential air thermometer in the form of a

straight glass tube with cylindrical bulbs, *c* and *d*, at each end; the whole inclosed in a protecting glass sheath, *a*. Mercury is used to separate the air in the two bulbs, a small quantity with a little alcohol being inserted in the bottom and stem of the lower bulb *d*, which bulb is smoothly coated on the outside with lampblack. The bulbs are filled with pure dry air and sealed. The space between the bulbs and the protecting sheath is then perfectly exhausted of air and also sealed.

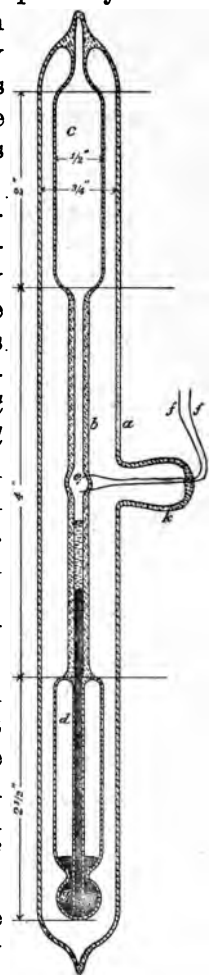

Fig. 4.—Sectional view showing construction.

Caution.—The instrument is very liable to derangement from the fact that the mercurial column will, if inclined from the vertical, rapidly run toward the upper bulb, and possibly allow the air to escape from one bulb to the other. If this occurs it will be necessary to readjust the instrument. After having been set, *the instrument should, therefore, be handled with great care, and the black bulb always kept lowermost.* Special pains should also be taken to see that the column of mercury does not become separated by bubbles.

32. In operation the glass instrument is mounted on the adjustable metallic base accompanying it, to which it is attached by means of a thumbscrew in a manner readily understood upon inspection.

33. In the latest pattern (1895) the platinum wires leading to the interior of the instrument pass through one large tubular projection at the center of the outside glass sheath, and are fused into the inner glass tube so as to be opposite each other. This arrangement prevents any loss of record on account of bubbles forming in the stem, as might happen with the 1893 pattern, and the one large tubulure affords a place for securely cementing on a metal cap to provide better protection for the wires. In the construction of these instruments a small quantity of alcohol has also been inserted in the lower, or blackened bulb, and also above the top of the mercurial column. This alcohol plays an important part in the thermometic action of the instrument, and also acts as a lubricant for the mercury. This instrument is shown mounted and in position in fig. 5.

34. *Exposure.*—An exposure similar to that for the photographic sunshine recorder (see paragraph 4) may be provided. Or, if more convenient, the instrument may be placed on top of the instrument shelter, or even attached to a wooden bracket clamped to the

wind vane or anemometer support. After being once satisfactorily set and adjusted it will rarely be necessary to examine or readjust this instrument. It is not, therefore, so important that it be easy of access, as is the case with the photographic sunshine recorder.

35. *Adjustment.*—When shipped from the Central Office the instrument is so adjusted that, with the bulbs at the same temperature and the instrument inclined at an angle of about 45°, the top of the mercurial column stands about half an inch below the connecting electrodes, as indicated in fig. 5. If carefully handled in transit this adjustment should not change, but if it is found that the column has changed in length any considerable amount, it should be readjusted before the instrument is attached to its metallic support for exposure.

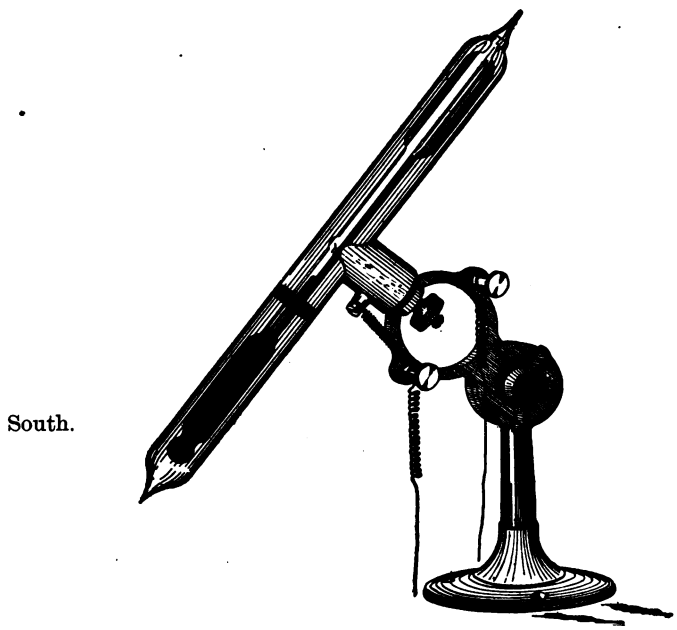

Fig. 5.—Thermometric sunshine recorder mounted.

36. To accomplish this it is necessary to pass a portion of the air from the lower to the upper bulb, if the mercurial column stands too *high*, or from the upper to the lower bulb if the column stands too *low*. A little judicious shaking of the instrument will usually accomplish this.

37. *First process.—When the mercury stands too high in the stem.*—The instrument must, in this case, be treated in such a manner as to pass air from the lower to the upper bulb. If the column is in detached portions the tube should be held nearly vertical and tapped sidewise on the palm of the hand, or otherwise

jostled so that the bubbles of air escape into the top bulb. If the column is still too high, more bubbles of air must be introduced into the tube from the lower bulb. For this purpose grasp the tube in the middle portion, holding it in a horizontal position, with the black bulb pointing forward. With a quick twist of the wrist and forearm rotate the tube a quarter turn or thereabouts so that the black bulb describes a short arc of a circle. The centrifugal force will have the effect of introducing considerable air into the tube from the lower bulb, and, on uniting the column of mercury, it will be found to stand very much lower if the operation has been rightly conducted.

Where it is desired to lower the column of mercury only slightly, a good plan is to jerk the instrument up and down smartly in a nearly vertical line. Small bubbles of air from the lower bulb are got into the tube this way, and these must then be worked up to top bulb by tapping sidewise.

38. *Second process.—When the mercury stands too low in the stem.*—In this case air must be forced from the top into the lower bulb. First, invert the instrument and joggle all the mercury in the tube into the clear bulb. If this is only a small quantity, jerk the tube up and down a little in the vertical position. This will cause some additional mercury from the black bulb to pass into the other bulb. After quite a globule of mercury has thus been placed in the top bulb, invert the instrument. The mercury closes the stem at the top end and imprisons the air therein. Grasp the instrument as you would in setting a maximum thermometer, by hand, as shown in fig. 6, and give it a free swing in a curved path. The centrifugal force will drive the mercury into the lower bulb and carry all or a portion of the air previously caught in the stem into the bulb.

Fig. 6.

A repetition or alternation of these processes will always serve to bring about the desired adjustment. Observers are cautioned not to use heat in affecting adjustments, notwithstanding that this was authorized in previous instructions.

39. If the observer is unable to readjust the instrument by following these instructions, it should be tagged with Form 4060 Misc.,

carefully packed and immediately returned to the Central Office (without metallic base), by railway or registered mail, in a wooden box, marked: Instrument Division. Facts to be reported by letter.

40. The adjustment having been perfected, the instrument attached to its hinged metal base and the base secured to the support on the roof so that the glass tube points north and south, with the *blackened bulb* toward the *south* and lowermost, it remains to incline the tube at such an angle that the instrument will begin and cease to record sunshine with the proper degree of cloudiness. This inclination will be approximately 45° from the vertical, at which angle the upper end of the mercurial column should stand about half an inch below the connecting electrodes.

41. *Critical condition for registration.*—The inclination of the recorder will be adjusted at such an angle that the mercury column will just close the electrical circuit during times when the disk of the sun can just be faintly seen through the clouds. If the cloudiness is such that the observer can not clearly distinguish the sun's disk, then the mercury should not rise high enough to close the circuit. Several trials on successive days may be necessary to secure the best adjustment. In altering the inclination of the recorder it is best to first make a chalk or pencil mark across the edges of the hinge joint of the support before it is loosened. Any change made in the inclination of the tube is then clearly shown by the amount the lines on the two parts of the hinge separate from each other. If it is desired to make a subsequent adjustment the first lines are easily erased and a new mark made.

42. Slightly different adjustments will probably be found necessary at different seasons of the year, from the fact that the normal position of the mercurial column is slightly changed by extremes of low and high temperatures.

43. It will also be found that an adjustment that gives the best results during the middle of the day fails to record all the sunshine when the sun is near the horizon, as the thermal effect of the sun is much greater when the sun is near the meridian. It is therefore best to adjust the recorder for a mean condition; that is, the adjustments should be made at about 9 a. m. or 3 p. m., under the critical conditions described in paragraph 41.

44. It must also be borne in mind that a thermometer constructed on the principle of this sunshine recorder is somewhat sluggish, so that when the sky is partly covered with floating clouds it must not be expected that the mercurial column will drop low enough to open the electrical circuit the *exact* instant the sun disappears behind a cloud, or rise high enough to close it the *exact* instant the sun comes out again. Small clouds and few moments of sunshine may, therefore, escape being recorded, but, in general, the time

lost after the sun commences to shine should equal the time gained after the sun disappears.

45. During partly cloudy weather the instrument should be watched carefully, and if it is found to be making an incorrect record a note to that effect will be made on Form No. 1017. After the observer has satisfied himself that the instrument systematically records either too little or too much sunshine, as indicated by the rule given above, he should endeavor to correct the error by a readjustment of the instrument. Frequent adjustments should, however, be avoided, but whenever made they should be noted on Form No. 1017, stating whether the new adjustment is more nearly horizontal or more nearly vertical than the old.

46. The electrical connections for attaching this sunshine recorder to the improved triple register will be found in Circular D, Instrument Division.

47. *Compilation of data.*—The meteorological data compiled from records obtained from the photographic sunshine recorder (Form No. 1065), and also from the thermometric sunshine recorder (Form No. 1017) will be tabulated on Form No. 1070. Detailed instructions relative thereto are given in circular A, Instrument Room, revised edition.

INSTRUCTIONS

FOR THE

CARE AND MANAGEMENT OF ELECTRICAL SUNSHINE RECORDERS.

CIRCULAR G, INSTRUMENT DIVISION,
FIFTH EDITION.

By C. F. MARVIN.

[Revised by H. C. Kaull, In charge of Instrument Division.]

WASHINGTON:
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1925.

CARE AND MANAGEMENT OF ELECTRICAL SUNSHINE RECORDERS.

1. *Registration of sunshine.*—While apparatus for continuous registration of the intensity of sunshine is now regularly employed at a few places, such apparatus is delicate, complicated, and expensive, and requires for successful operation and maintenance, and for the interpretation of the records, the attendance of specialists. Such instruments, known as pyrheliometers, pyranometers, pyrgeometers, etc., are described in papers that have appeared in the MONTHLY WEATHER REVIEW from time to time.

2. *Registration of duration of bright sunshine.*—The Campbell-Stokes recorder, which consists of a ground and polished glass sphere that acts as a lens or burning glass, and scorches a trace showing the duration of bright sunshine upon a strip of cardboard placed at the proper focal distance from the sphere, is much used in Europe and other parts of the world. The Jordan photographic recorder, in which the apparent movement of the sun across the sky traces a line on slips of sensitized photographic paper, was formerly used to some extent in the Weather Bureau, but it has now been practically discontinued in favor of the electrical sunshine recorder, because the latter is well adapted to registration along with other meteorological data on the triple register maintained at all first-order Weather Bureau stations.

3. *The electrical sunshine recorder.*—The principle employed is similar to that of Leslie's differential air-thermometer, which has been known more than a hundred years.[1] A glass tube containing a liquid terminates in two bulbs, both containing air. In the original Leslie thermometer both bulbs were uppermost, and were joined together by the tube., bent into the form of a U, the liquid occupying one leg and only part of the other leg of the U. If both bulbs have the same temperature, the liquid must remain stationary; but if one of the bulbs be warmed, the expanding air will depress the liquid in the stem; or if it be cooled, the contracting air allows the liquid to rise. In the original Leslie instrument the stem was suitably graduated to indicate numerically the difference in temperature between the two bulbs, and it was used in a number of interesting ways, such as to measure the flow of heat from a fireplace, the strength of sunshine, the depression of the wet bulb, etc.

[1] Leslie, John, esq.: Description of Instruments (Meteorological) Edinburgh, 1820.

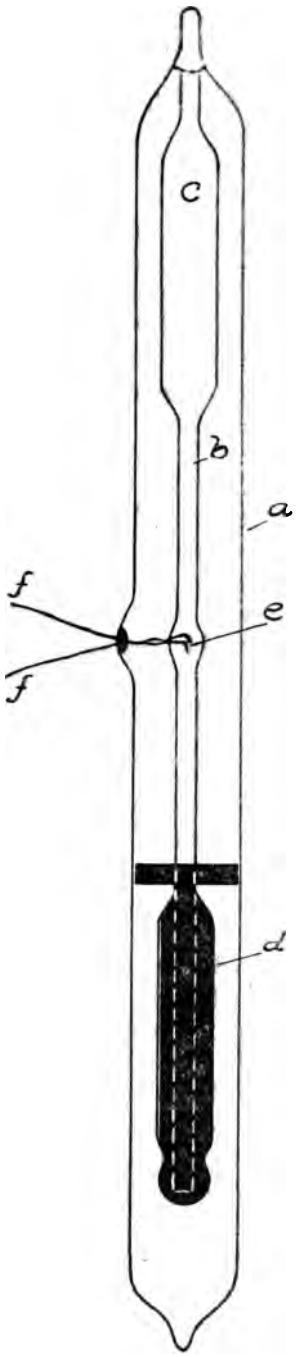

FIG. 1.—Conventional diagram of glass part of sunshine recorder, unmounted.

4. The glass portion of the instrument is shown in Figure 1. The upper chamber *c* is narrowed into a slender tube, *b*, which extends almost to the bottom of the lower chamber *d*. Now when mercury is introduced, generally by means of a long, slender funnel extending to the bottom of chamber *d*, the mercury rises in both the tube *b* and the chamber *d*, so that the height to which the surface of the mercury ascends in chamber *d* is limited by compression. Hence if more mercury is added it will continue to rise in the tube *b* until the desired quantity has been introduced—generally enough to fill the tube to a point about one-half inch below the upper chamber when the instrument stands vertically in the shade. A little alcohol is then added to serve as a lubricant and a preventive of undue sparking, and the top end sealed off. Both mercury and alcohol should be of a high degree of purity, since experience has shown that slight impurities, particularly alcohol containing a small per cent of water, interfere with the proper performance of the instrument, and hasten deterioration.

5. *Vacuum jacket.*—The outer glass jacket *a* serves to inclose the thermometric device in a space from which the air has been exhausted to render the thermometer insensible to ordinary air-temperature changes, on the principle of the thermos bottle.

6. *Platinum wires.*—Two platinum wires, *f*, *f*, fused through the walls of both glass sheath and thermometer tube are connected through suitable binding posts with a pair of wires that join in series a battery and the registering device in the office.

7. *Operation.*—The lower bulb is coated with lampblack; hence when sunshine falls upon the instrument the air in the lower bulb will become warmer than the air in the upper clear glass bulb. The consequent expansion of the air in the lower bulb exerted against the surface of the mercury

FIG. 2.—Sunshine recorder, assembled.

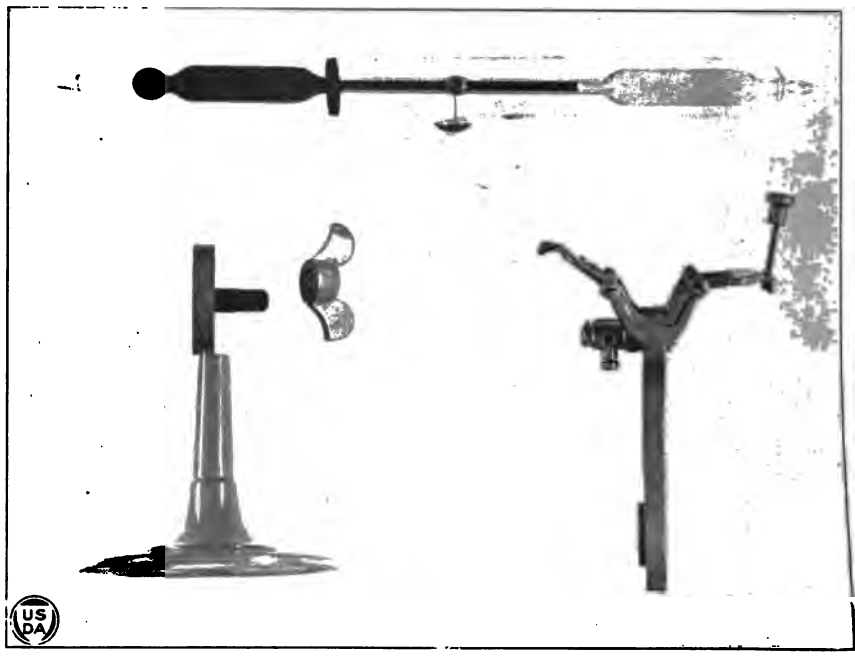

FIG. 3.—Parts of sunshine recorder and mounting, disassembled.

causes a corresponding rise of the mercury in the tube. Registration begins when the mercury reaches the inner ends of the two platinum wires *e*, and continues until it has receded below them. Excess of mercury, due to stronger sunshine, merely stands higher in the tube, the registration being the same.

8. *Mounting.*—The mounting is in two sections as shown in Figure 2, the lower section being in the form of a flanged base with screw holes conveniently arranged for attaching it to a support, and bearing a serial number. The upper section is clamped to the lower section in a way to form a hinged joint that permits angular adjustment to the critical condition for registration.

9. *Requisition for sunshine recorders or parts.*—As instruments of different styles are in use at stations, requests should clearly indicate what is desired by appropriate reference to illustration, or by specific description. Sketches are helpful. The latest pattern is shown dissembled in Figure 3.

10. The lower flanged base section has remained unchanged in design for many years, and is practically uniform throughout the Bureau; but the upper section, which was formerly constructed in a way that rendered it practically integral with the glass tube, has been redesigned to permit the insertion of a new tube at stations.

11. *Caution to be observed in assembling parts.*—As the tubes are made of thin glass, which is easily crushed, the clamp should be drawn only tight enough to insure a firm grip. *Necessary bends in the platinum wires should be made at some distance from the glass*, since they are liable to break if bent short where they emerge.

12. *Exposure.*—It is obvious that the instrument should be placed where the sun will fall upon it every day throughout the year with the least possible interference. Ideal conditions of exposure are not always to be had, and it is, hence, necessary to select the best available. Fortunately the sunshine recorder does not require frequent attention, hence the question of accessibility is less important than in the case of other meteorological instruments. A slender flagstaff or similar object may intervene with no more serious result than to produce a slight break in the continuity of the record at the same hour every day. Low objects near the horizon do not materially affect the instrumental record, since the sunshine is not strong enough to cause registration during the early morning or late evening hours.

13. *Rigidity of support.*—The support should be sufficiently rigid to prevent vibration due to wind, which may cause objectionable momentary contacts of the mercury with the platinum wires.

14. *Orientation.*—The black bulb should be toward the south.

15. *Adjustment.*—The instrument is quite likely to be so disturbed in shipment as to require adjustment of the mercury column. This

is effected by passing a portion of air from the lower to the upper bulb if the mercuy column stands too high, or from the upper to the lower bulb if the column stands too low.

16. *When the mercury stands too high.*—First, holding the instrument vertically, jostle the instrument up and down to reunite the mercury column, if broken, as is generally the case. Then to pass air from the lower to the upper bulb, grasp the instrument with black bulb downward and let the hand and arm perform a reverse circular movement as indicated in Figure 4. The hand should be kept reasonably close to the body, and the circle need not be large nor the movement rapid. At the lowermost part of the throw the inertia of the mercury carries a portion into the lower bulb and permits a corresponding amount of air to escape into the upper bulb.

17. *When the mercury stands too low.*—In this case air must be passed from the clear to the black bulb. Invert the instrument and get as much mercury into the clear bulb as convenient. Then rather quickly invert the instrument again so that as the mercury falls into the narrow tube it may form a stop to imprison the air in the tube. The instrument is then jerked up and down in a way to force the imprisoned air into the lower tube. The processes are repeated or alternated until the desired adjustment has been accomplished.

18. *Installation.*—The adjustment having been perfected, the instrument attached to its hinged metal base, and the base secured to the support on the roof so that the blackened lower end of the glass tube points south, it remains to incline the tube at such an angle that the instrument will begin and cease to record sunshine with the proper degree of cloudiness. This inclination will be approximately 45° from the vertical, at which angle the upper end of the mercurial column should stand about half an inch below the connecting electrodes.

19. *Critical condition for registration.*—The inclination of the recorder will be adjusted at such an angle that the mercury column will just close the electrical circuit during times when the disk of the sun can be just faintly seen through the clouds. If the cloudiness is such that the observer can not clearly distinguish the sun's disk, then the mercury should not rise high enough to close the circuit. Several trials on successive days may be necessary to secure the best adjustment. In altering the inclination of the recorder it is best to first make a chalk or pencil mark across the edges of the hinge joint of the support before it is loosened. Any change made in the inclination of the tube is then clearly shown by the amount the lines on the two parts of the hinge separate from each other. If it is desired to make a subsequent adjustment, the first lines are easily erased and a new mark made.

FIG. 4.—Illustration of method used to force mercury into the lower bulb.

20. *Seasonal adjustment.*—Slightly different adjustments will probably be found necessary at different seasons of the year, from the fact that the normal position of the mercurial column is slightly changed by extremes of low and high temperatures.

21. It will also be found that an adjustment that gives the best results during the middle of the day fails to record all the sunshine when the sun is near the horizon, as the thermal effect of the sun is much greater when the sun is near the meridian. It is therefore best to adjust the recorder for a mean condition; that is, the adjustments should be made at about 9 a. m. or 3 p. m., under the critical conditions described in paragraph 19.

22. It must also be borne in mind that a thermometer constructed on the principle of this sunshine recorder is somewhat sluggish, so that when the sky is partly covered with floating clouds it must not be expected that the mercurial column will drop low enough to open the electrical circuit the exact instant the sun disappears behind a cloud, or rise high enough to close it the exact instant the sun comes out again. Small clouds and few moments of sunshine may, therefore, escape being recorded, but, in general, the time lost after the sun commences to shine should equal the time gained after the sun disappears.

23. During partly cloudy weather the instrument should be watched carefully, and if it is found to be making an incorrect record a note to that effect will be made on Form No. 1017. After the observer has satisfied himself that the instrument systematically records either too little or too much sunshine, as indicated by the rule given above, he should endeavor to correct the error by a readjustment of the instrument. Frequent adjustments should, however, be avoided, but whenever made they should be noted on Form No. 1017, stating whether the new adjustment is more nearly horizontal or more nearly vertical than the old.

24. The elecrtical connections for attaching this sunshine recorder to the triple register will be found in Circular D, Instrument Division.

25. *Caution.*—The sunshine recorder should be removed to the office or otherwise protected when painting or structural work is being done. Eye observation of sunshine with appropriate notation should be entered on the forms for the missing period.

26. *Compilation of data.*—The meteorological data compiled from records obtained from the thermometric sunshine recorder (Form No. 1017) will be tabulated on Form No. 1001. Detailed instructions relative thereto are given in Circular A, Instrument Division, third edition, and in Instructions for Preparing Meteorological Forms.

27. *Sunshine tables.*—Monthly card tables giving sunshine data in the local standard of time authorized to be used will be prepared in

duplicate sets at each station where required in compiling sunshine data. Each set will comprise a card table for each month of the year with the appropriate data entered for each day of the month. For this purpose the necessary blank card forms and a complete set, Parts I, II, and III, of the sunshine tables, in mean solar time (Edition 1905), will be sent as required. One set of the station tables will be retained and used in the tabulation of sunshine data, in accordance with existing instructions. The duplicate set, after having been carefully compared and verified, will be forwarded to the central office in a package marked "Climatological Division."

28. *Time limit.*—Thirty days after receipt of cards are allowed for the completion of the tables, but the card for the month in which sunshine forms are first compiled from the tables must be forwarded as soon after the receipt of cards as practicable.

29. *Time correction.*—The correction, in minutes of time, that is required to reduce mean solar time to the local standard of time in current use at the station, will be entered with its appropriate algebraic sign at the head of each card. The minus sign will be used if the correction is to be subtracted from mean solar time, and plus if the correction is to be added. If mean solar time is the standard time in use at any station, the time correction will be zero, and the card tables will be prepared accordingly.

30. *Latitude.*—The station table will be computed from the printed table for the whole degree of latitude nearest that of the station, following the usual rule for dropping fractions; for example:

46° 30′ will be taken as 46°.
41° 30′ will be taken as 42°.

31. *Sunrise and sunset.*—The times of sunrise and sunset will be first computed from the printed table by applying the "time correction" at the top of the card.

32. *Fractional hours.*—The possible sunshine during hours ending shortly after sunrise and sunset will, for brevity, be styled fractional hours, and these data will be entered on the card in the columns provided, and will be computed in hundredths of hours, as follows:

33. The minutes in the time of sunrise, as tabulated on the card, will be subtracted from 60; the remainder thus obtained divided by 60, and the quotient, in hundredths of hours, placed in the appropriate "A. M." column. The minutes in the time of sunset will be divided by 60 and the quotient, in hundredths of hours, set in the appropriate "P. M." column.

34. Enter at the top of these "A. M." and "P. M." columns the morning and evening hours, in sequence, at which fractional hours of sunshine terminate during any portion of the month.

35. *Totals.*—The total sunshine for each day of the month will be computed by adding together the a. m. and p. m. fractional hours and the number of whole hours of sunshine that is possible between the fractional hours.

36. The monthly totals for each column of possible sunshine will also be computed.

37. These daily and monthly totals will finally be entered upon the cards to the nearest tenth of an hour only, but, in order to check and adjust the computation, as further explained in the next paragraph, it is best to first set down on pencil paper all totals in hundredths, since otherwise, the usual rule for dropping decimals will sometimes fail to give the necessary agreement in the final results.

38. *Checks.*—The total sunshine for the month, in hundredths, should check exactly with the sum obtained by adding all the totals for the fractional hours, plus the intervening whole hours of sunshine multiplied by the number of days of the month.

39. The computation having been thus checked, the daily and monthly totals will be entered upon the cards to the nearest tenth, the hundredths being dropped according to the usual rule, except that the total possible sunshine for the month will always be taken directly from the printed table, even if it differs slightly from the sum of the daily totals.[2]

40. *Station tables.*—The verified values on the cards will constitute the sunshine tables used in the preparation of all station forms and records.

41. *Divisors.*—The monthly sums of the a. m. and p. m. fractional hours constitute the "divisors" which are to be employed at the end of the month in computing the monthly percentages of possible sunshine recorded during the hours ending shortly after sunrise and sunset, as tabulated on Form No. 1001, page 4.

42. *Example.*—The foregoing instructions are elucidated by the sample computation which follows.

[2] The values in the printed table are derived directly from fundamental data computed to the tenth of a minute, and are more accurate than modified values obtained therefrom.